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Economic Security: Neglected Dimension of National Security?

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TECHNOLOGY CONVEGENCE and NATIONAL SECURITY

Dr. James J. Valdes

Economic Security:

Neglected Dimension of National Security?

COURT OF THE MEDICI'S

An early example of the power of convergence

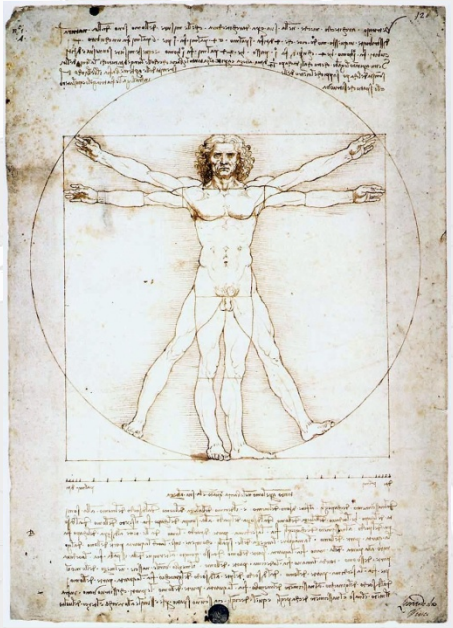
Leonardo da Vinci

Lorenzo the Magnificent

Michelangelo Buonarroti

Sandro Botticelli

Andrea del Verrocchio



The Virtruvian Man

The convergence of the best minds from science, medicine, philosophy and the arts at the Medici Court in 15th Century Florence catalyzed the Renaissance. It was the transdisciplinary nature of that convergence that was critical.

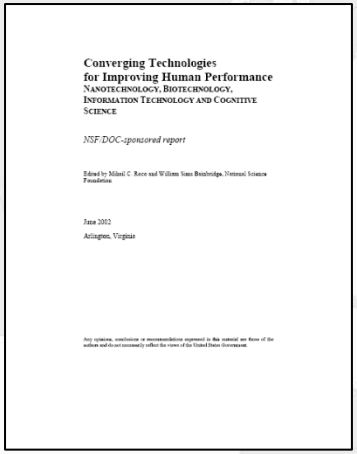
BACKGROUND LOGIC

- **Many traditional R&D programs have been commodity or capability driven, and based on a perceived threat rather than science and technology**
  - Creates artificial technology stovepipes and incremental advances
  - Results in never ending game of catch-up to emerging threats
  - In corporate world, tends to preserve *status quo* and miss disruptive technologies
- **We need a transdisciplinary revolution:**

  an integrated and comprehensive science and technology approach that transcends traditional disciplines and instead looks at knowledge as a broad-based continuum to transform military and commercial capabilities
  - Principles from one discipline fundamentally alter how we think of another discipline (e.g. neuroscience and computers)
  - Exponential leaps in technology result from transdisciplinary convergence (e.g. genomics and information technology)
  - Ability to negate all military and economic threats, whether known or unknown, and exploit disruptive technologies

TRANSDISCIPLINARY SCIENCES

In order to transform the current paradigm of incremental improvements, we need to leap ahead and embrace truly revolutionary concepts as well as emergent, integrated and cross-cutting technologies –
such as combining recent dramatic advances in
Nanotechnology-Biotechnology-Information Technology-Cognitive (NBIC)
sciences


Converging Technologies
for Improving Human Performance
NANOTECHNOLOGY, BIOTECHNOLOGY,
INFORMATION TECHNOLOGY AND COGNITIVE
SCIENCE

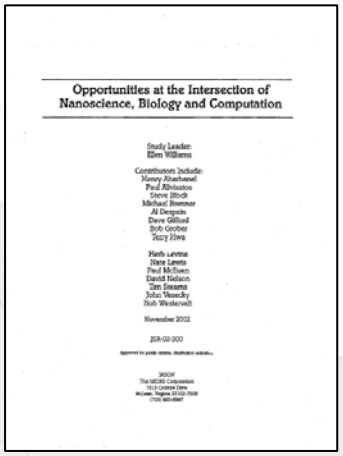
NSF/DOC-sponsored report

Edited by Mihail C. Roco and William Sims Bainbridge, National Science Foundation

June 2002
Arlington, Virginia

Any opinions, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the United States Government.

National Science Foundation Jun 02


Opportunities at the Intersection of
Nanoscience, Biology and Computation

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JASON Study Nov 02

Changing the societal "fabric": towards a new structure
(upper figure by R.E. Horn)

NBIC is a metaphor


Nano-Bio-Info-Cogno-Socio-Anthro-Philo-

HLEG
Foresighting the New Technology Wave

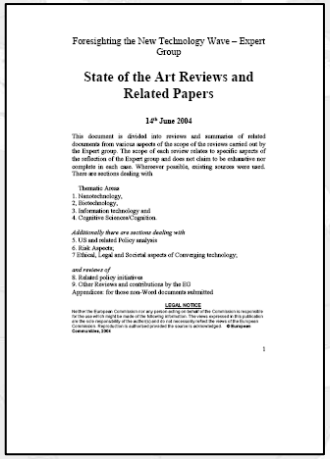
Converging Technologies –
Shaping the Future of European
Societies

by Alfred Nordmann,
Rapporteur

Report
2004

Geo-Eco-Urbo-Orbo-Macro-Micro-Nano-

European Commission HLEG Study 2004


Foresighting the New Technology Wave – Expert Group

State of the Art Reviews and Related Papers

14th June 2004

This document is divided into reviews and summaries of related documents from various aspects of the scope of the reviews carried out by the Expert group. The scope of each review relates to specific aspects of the reflection of the Expert group and does not claim to be exhaustive nor complete in each case. Wherever possible, existing sources were used. There are sections dealing with

Thematic Areas
1. Nanotechnology,
2. Biotechnology,
3. Information technology and
4. Cognitive Sciences/Cognition.

Additionally there are sections dealing with
5. US and related Policy analysis
6. Risk Aspects,
7 Ethical, Legal and Societal aspects of Converging technology;

and reviews of
8. Related policy initiatives
9. Other Reviews and contributions by the EG
Appendices: for those non-Word documents submitted

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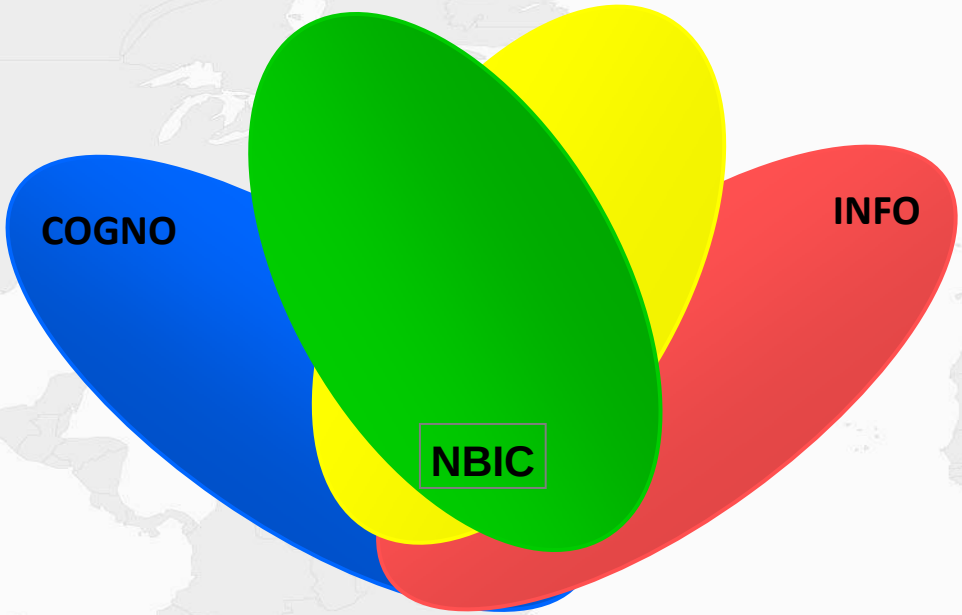
European Commission HLEG Jun 04

TRANSDISCIPLINARY SCIENCE APPROACH

Each of the intrinsically multidisciplinary N,B,I,C research fields should become embedded in current programs and strategic planning

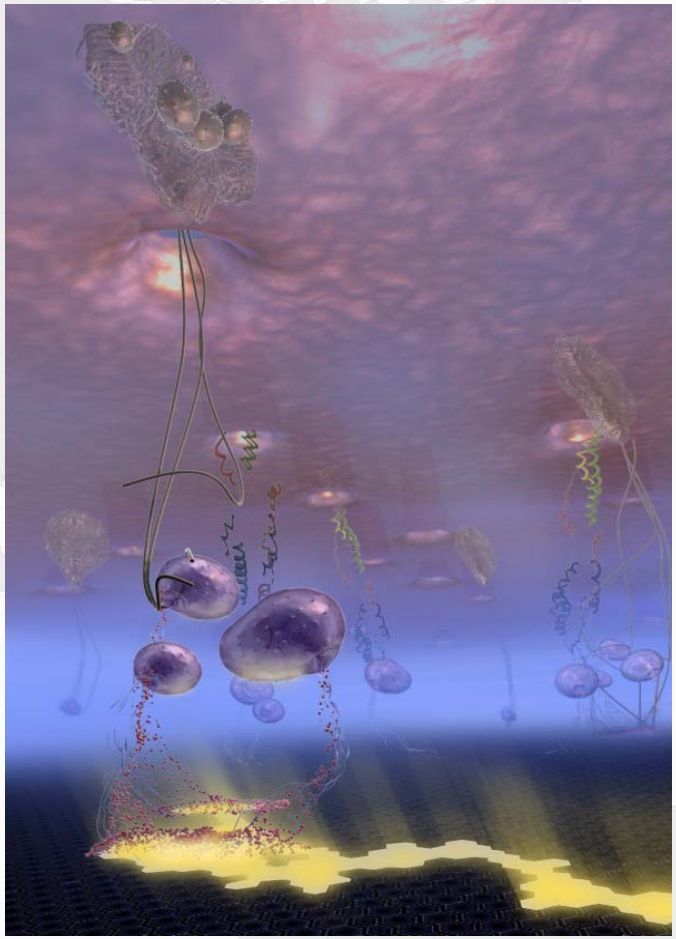


Revolutionary Capabilities REQUIRE

- **focused**
- **integrated**
- **cross-cutting**
- **cross-functional**
- **transformational concepts and experimentation**

Transformational Concepts emerge where **N, B, I, C** S&T converge to NBIC S&T at a single notion: e.g. understanding molecular functions, processes and architectures essential to humans towards an ultimate goal of mimicking those functions, mechanisms, processes, and architectures via synthetic routes.

EXAMPLES OF TRANSDISCIPLINARY GOALS



Completely abiotic systems capable of sensing, analysis and response, and adapting to the environment

- Development and synthesis of tailored materials such as nanosensors
- Built in transduction and amplification of chemical signals into electronic signals
- Inherent redundancy, orthogonal sensor fusion, signal preprocessing and telemetry
- Seamless integration into all platforms

Networked embedded systems

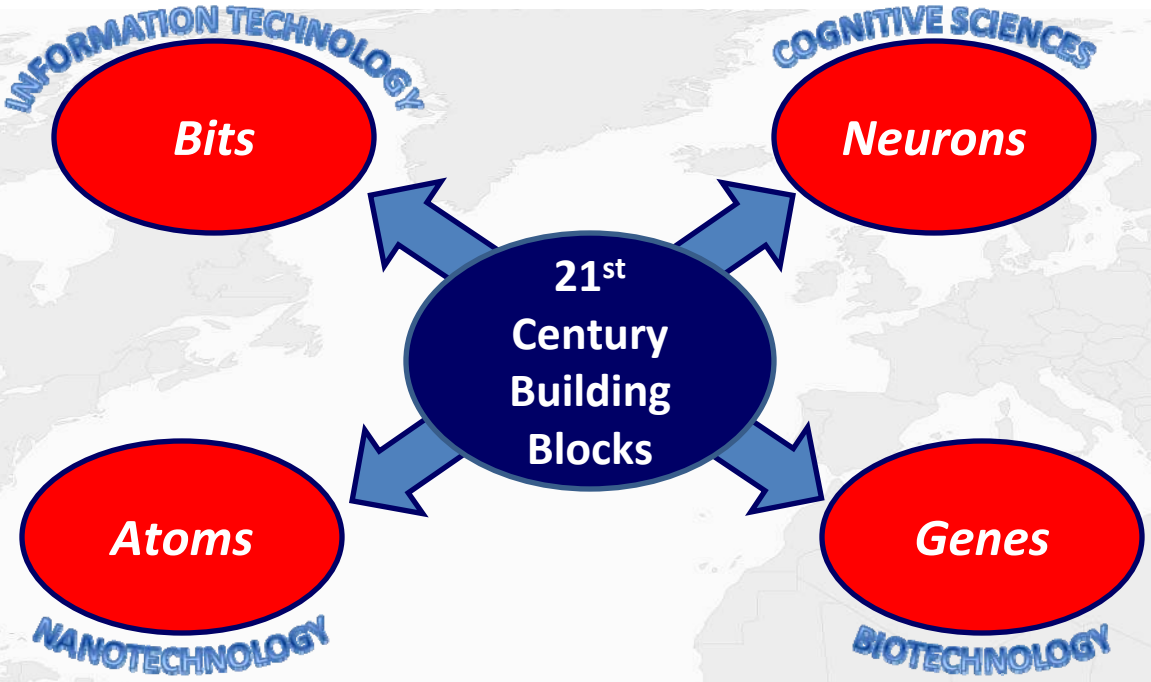
- Artificial intelligence based cognitive elements for sensor fusion and threat analysis
- Self organizing and repairing, adaptable to changes in network connectivity and membership, scalable
- Ability to react autonomously and transparently
- Capable of emergent properties

TRANSDISCIPLINARY KNOWLEDGE CAMPAIGNS

S&T Priority Areas	Description
COMPLEX ABIOTIC SYSTEMS*	Understand how to build systems that capture the functionality of biotic systems with non-living (abiotic) materials in order to provide revolutionary capabilities to sense, respond, and adapt to the environment.
PANOMICS*	Demonstrate real time, high fidelity identification and characterization of genomic, transcriptanic, proteomic and metabolomic data leading to personalized medicine.
EMERGENT INFORMATION SCIENCE FRAMEWORK*	Develop and demonstrate intelligent, self-aware bio-mimetic systems that sense, investigate, respond, and adapt with emergent properties.
COGNITIVE SCIENCES*	Develop and demonstrate capabilities to maintain, enhance, and recover human/machine decision making performance in a complex environment.
ENERGY AT SMALL SCALES*	Understand and develop physical and biological processes for improved power generation or scavenging, energy storage, and distribution at micro and nano scales.

Click individual Knowledge Campaigns above for more detail

CONVERGENCE



If the ***Cognitive Scientists*** can think it

the ***Nano*** people can build it

the ***Bio*** people can implement it, and

the ***IT*** people can monitor and control it

From a 2001 NBIC workshop participant (W.A.W.)

POTENTIAL OF CONVERGING TECHNOLOGIES

Address core goals of individuals and society

- Strategy for technological and economical competitiveness
- Enhancing individual and group abilities, productivity and learning
- New patterns for S&T, business, economy, and society
- Changing human activities towards the “innovation age”
- Sustainable and “intelligent” environments

SOME KEY NBIC DRIVERS

- Market driven economy and business advantage
- Rising health care costs
- Maintaining military technological superiority
- Environment concerns

Bio-Inspired Technologies

- Bio-derived energy
  - Biodiesel from algae
  - Ethanol, butanol, methanol
  - Waste to Energy
  - Fuel cells
- Personal Protection and Armor
  - Spider silk
- Personal Medicine
  - Panomics based medicine

Bio-Inspired Technologies

- Biomanufacturing
  - Room temperature synthesis of energetic materials
  - Genetically engineered production of pharmaceuticals
  - Feedstock for bulk materials
  - Enzymes for environmental remediation
- Robotics
  - Biomimetic design of miniature UAVs
  - Rough terrain mules
- Biological computing
  - Beyond the limitations of silicon
  - Robots made of mold

THE END

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Knowledge Campaign: Complex Abiotic* Systems

Description:

Understand how to build systems that capture the functionality of biotic systems with non-living (abiotic) materials in order to provide revolutionary capabilities to sense, respond, and adapt to complex environments

Complex Abiotic Systems Research is key to realizing these ***Notional Product Concepts:***

- Independent nano devices
- Self repairing materiel
- Synthetic human physiology

	5 yrs	10 yrs	15 yrs
Complex Abiotic Systems	Build an i*n-vitro* system to demonstrate the use of initial i*n-silico* rules to design a functional pathway and ability to use standard bio-bricks to build pathways necessary for functional products	Systems with increased complexity and functionality, for example: – Self-reporting – Self contained in a structural matrix such as a fabric, coating or skin-like material – Sense and adapt – Smart – Integrate with EIS, Panomics	• Complete system providing transparent, real-time environmental assessment and mitigation • System must integrate advances in transdisciplinary sciences to be able to sense, respond, act, self-repair, self-power and be contained in a self-made structural matrix

Knowledge Campaign: Panomics*

Description:

- Demonstrate real time, high fidelity detection and characterization of all known and unknown threats
- Protect individuals by characterizing individual sensitivities to xenobiotics* leading to personalized interventions

Panomics Research is key to realizing these ***Notional Product Concepts:***

- Signatures and diagnostic biomarkers for autonomous triggering and application of personalized medicine
- Physiological markers for development of synthetic human physiology-based sensor

	5 yrs	10 yrs	15 yrs
Panomics	• Sets of unique and pan-specific signatures from host and/or pathogens, including emerging or engineered pathogens • Integration for autonomous classification of biomarkers signatures (EIS)	• Understanding and characterizing the variability in host response to health threats and treatments • Integration with decision making for host response to disease (EIS and Cognitive Science)	• Complete system providing transparent, real-time disease identification and mitigation • System must integrate advances in transdisciplinary sciences to be able to sense, respond, act, self-repair, self-power and be contained in a self-made structural matrix

* Panomics: The use of genomics, metabolomics, proteomics to characterize an organism at the molecular level.
* Xenobiotics: a substance originating outside the body (chemical, biological, therapeutic).

Knowledge Campaign: Emergent Information Science

Description:

- Develop and demonstrate intelligent, self-aware bio-mimetic equipment and systems that sense, investigate, respond, and adapt to all contingencies

Emergent Information Science Research is key to realizing these ***Notional Product Concepts:***

- Information needed for equipment to be situationally aware, adaptive and responsive
- Information infrastructure for smart skin or smart coatings for materiel
- Physiological monitoring and health status surveillance
- Deliver knowledge discovery, data fusion, and predictive learning techniques to understand physiological status and classify biomarker signatures
- Create non-specific early (prodomic) indicators to predict health and environmental threats

	5 yrs	10 yrs	15 yrs
Emergent Information Science	• Ability to transmit, discover, integrate, and understand (make sense of) information among a network of smart systems • Integration for autonomous classification of biomarker signatures (Panomics)	• Integration with decision making for host response to a threat (Panomics and Cognitive Science) • Smart information infrastructure with emergent properties	• Complete system providing transparent, real-time environmental identification and mitigation • System must integrate advances in transdisciplinary sciences to be able to sense, respond, act, self-repair, self-power and be contained in a self-made structural matrix

Knowledge Campaign: Cognitive Sciences

Description:

– Develop and demonstrate capabilities to maintain, enhance, and recover human/machine decision making performance in complex scenarios

Cognitive Sciences Research is key to realizing these ***Notional Product Concepts:***

– Cognitively enhanced system: The ensemble of human and information processing machines for problem solving, decision making, and situational awareness

– Virtual mask cognitive interface

– Efficient compression of meaning

– Mitigation of cognitive impairment under stress

	5 yrs	10 yrs	15 yrs
Cognitive Sciences	• Models of human neural and cognitive expression under stress • Algorithms to sense and supplement diminished human cognition • Integration for autonomous classification of biomarker signatures; (EIS and Panomics)	• Predictive theories of human neural and cognitive function. • Models of dynamic human and machine workload sharing • Integration with decision making for host response to a threat (EIS and Panomics • link to biomarkers	• Complete system providing transparent, real-time environmental identification and mitigation • System must integrate advances in transdisciplinary sciences to be able to sense, respond, act, self-repair, self-power and be contained in a self-made structural matrix

Knowledge Campaign: Energy at Small Scales

Description:

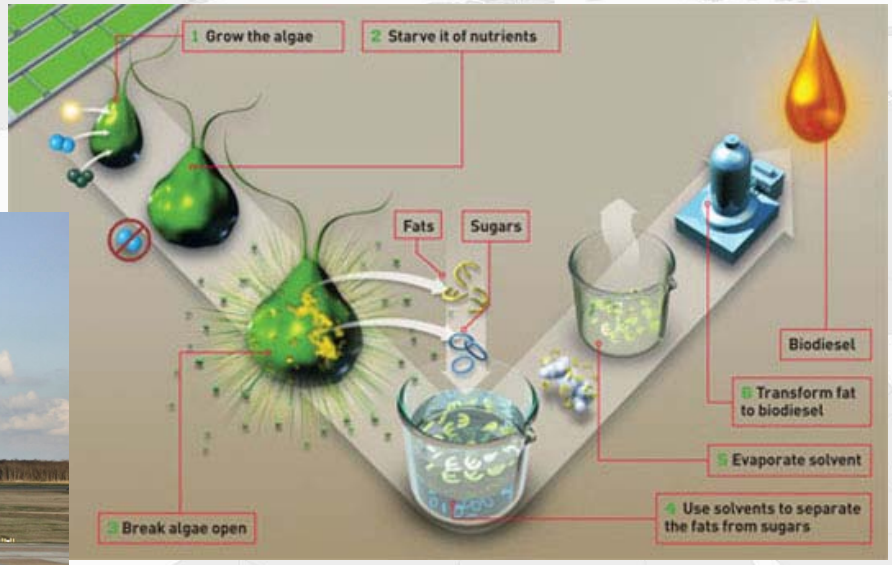
- Physical and biological processes for improved power generation or scavenging, energy storage, and distribution at micro and nano scales
- Includes electron and energy transfer processes, charge transport effects, biological energy harvesting mechanisms, interfacial phenomena, nanoscale phase equilibria

Research in Energy at Small Scales is key to realizing these ***Notional Product Concepts:***

- Nano fibers with the capability to harvest kinetic energy integrated into textiles from motion
- Photovoltaic materials integrated in coatings such as paints or textiles
- Thermo-electric materials integrated into suits or abiotic devices

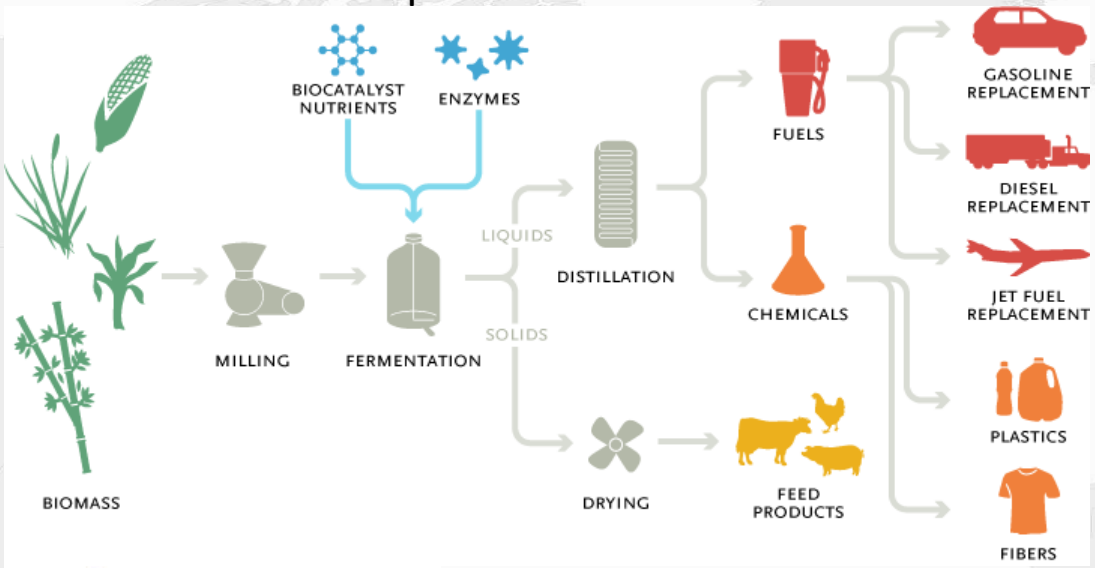
	5 yrs	10 yrs	15 yrs
Energy at Small Scales	• Bio inspired devices for solar collection • RF/EM harvesting • Kinetic and mechanical energy harvesting materials. • Structural power/architectural integration for collection, storage and distribution	• Solar concentrators at small scales • Materials for micro/nano sized photovoltaics • Mems scale EMF power generation • Broadband mechanical/kinetic/vibrational energy harvesting devices	• Complete system providing transparent, real-time threat identification and mitigation • System must integrate advances in transdisciplinary sciences to be able to sense, respond, act, self-repair, self-power and be contained in a self-made structural matrix

Biodiesel from Algae

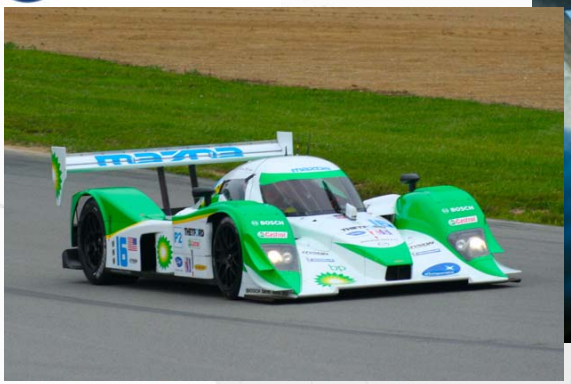


Ethanol, Butanol & Methanol

GEVO production Process



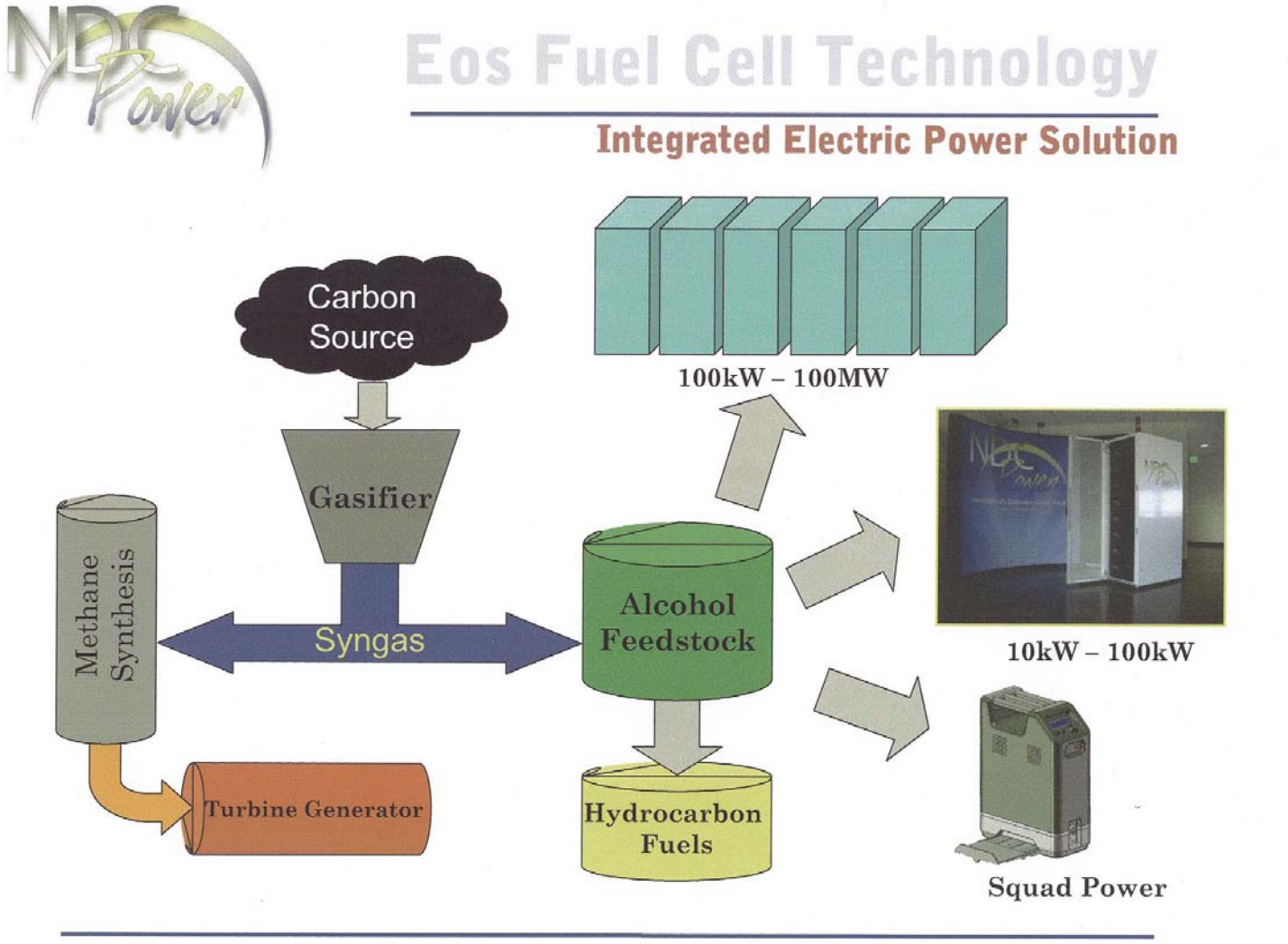
gevo™



Waste to Energy

A TGER is a waste-to-energy system that combines two complementary technologies, advanced fermentation and thermal decomposition, to give it the ability to convert a broad range of military waste products to energy. This hybrid system produces a high energy blend of synthetic gas and ethanol which is used to power military generator sets. TGER units, which can be transported in standard shipping containers and towed on a five ton trailer, are designed for tactical and post combat stabilization scenarios. Each TGER can convert a ton of waste per day to energy, reducing the logistics and security burden of transporting fuel to forward operating bases and combat outposts.

Fuel Cells

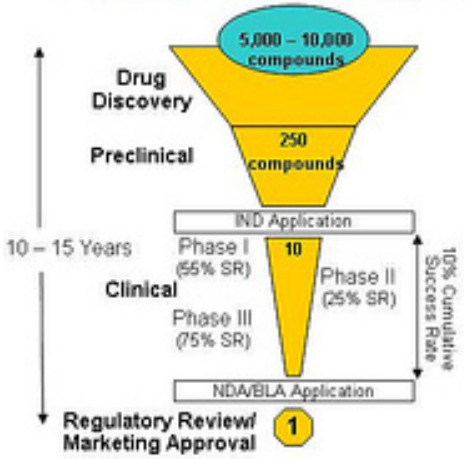


Spider Silk - Armor

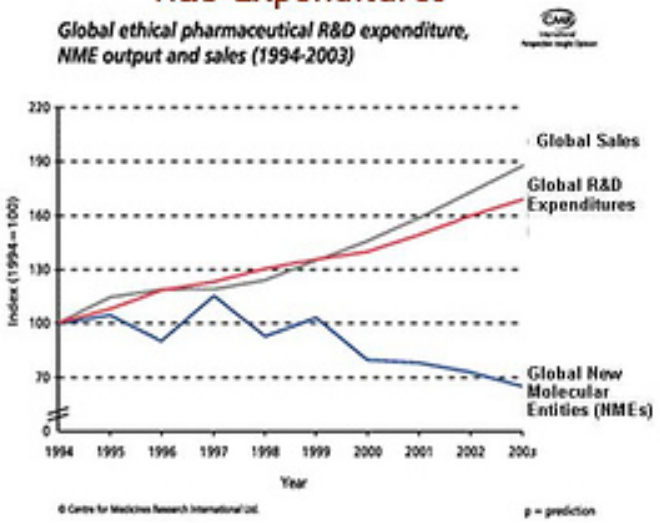
Panomics Based Medicine

Big Pharma : Dramatic Decline in R&D Productivity

Attrition Remains Very High

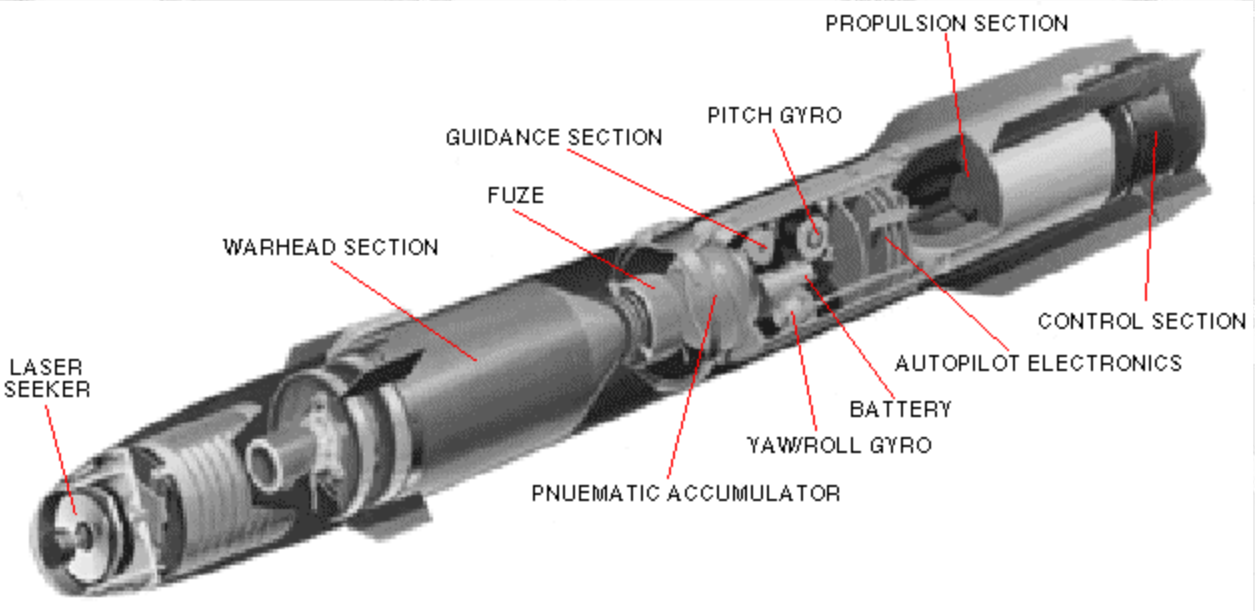


Output Not Keeping Up With R&D Expenditures



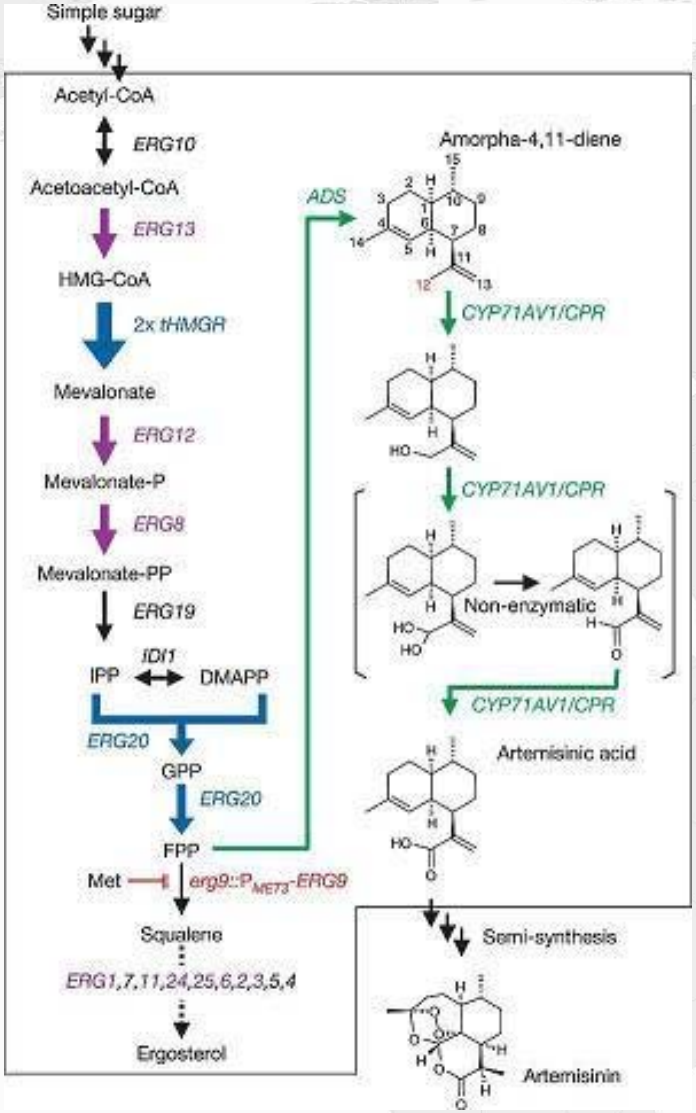
Source: PhRMA, CMR, Genentech, Booz Allen Hamilton: *The Global Innovation 1000*, 2006

Room Temperature Synthesis of Energetic Materials

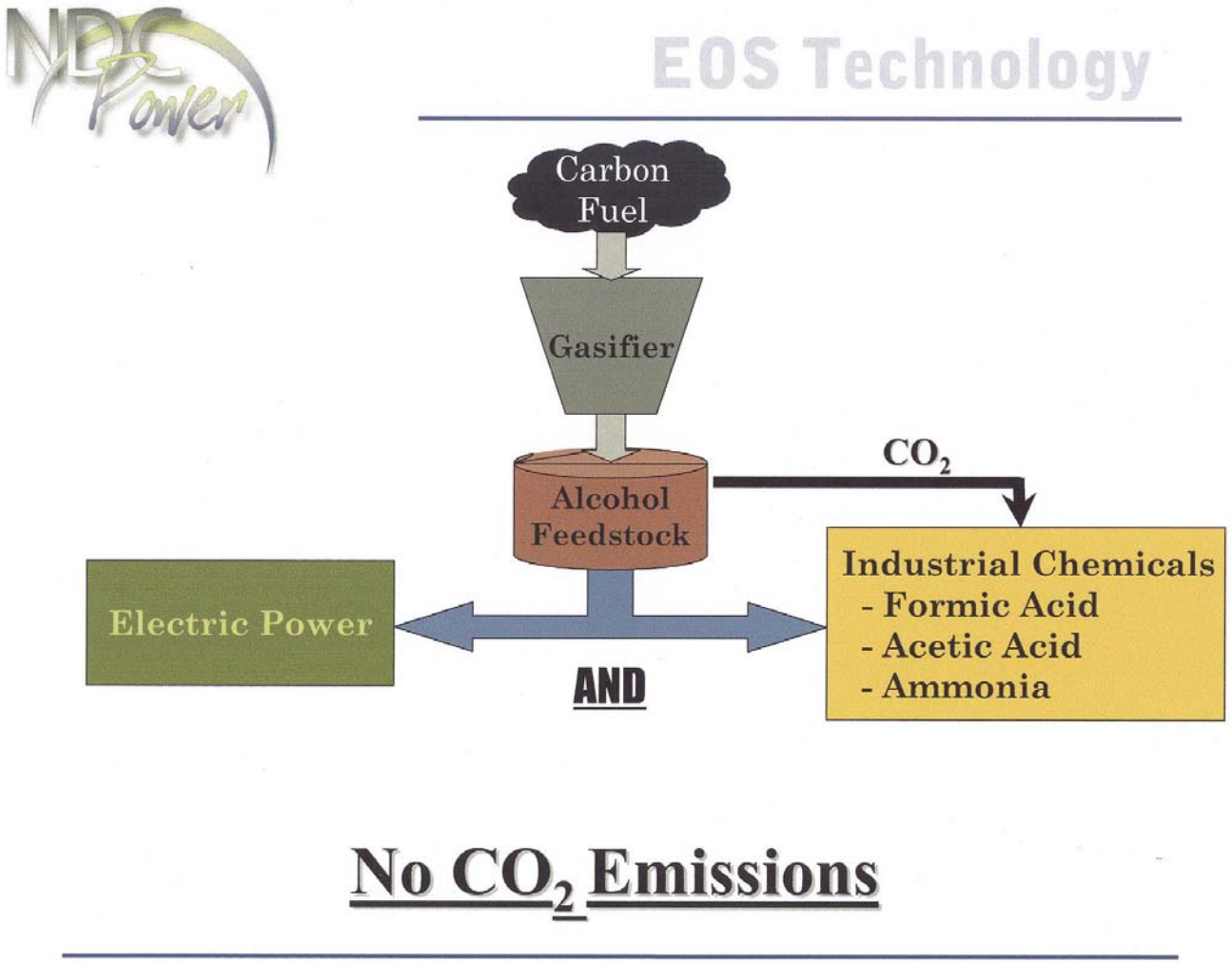


Hell Fire Missile

Genetically Engineered Production of Pharmaceuticals

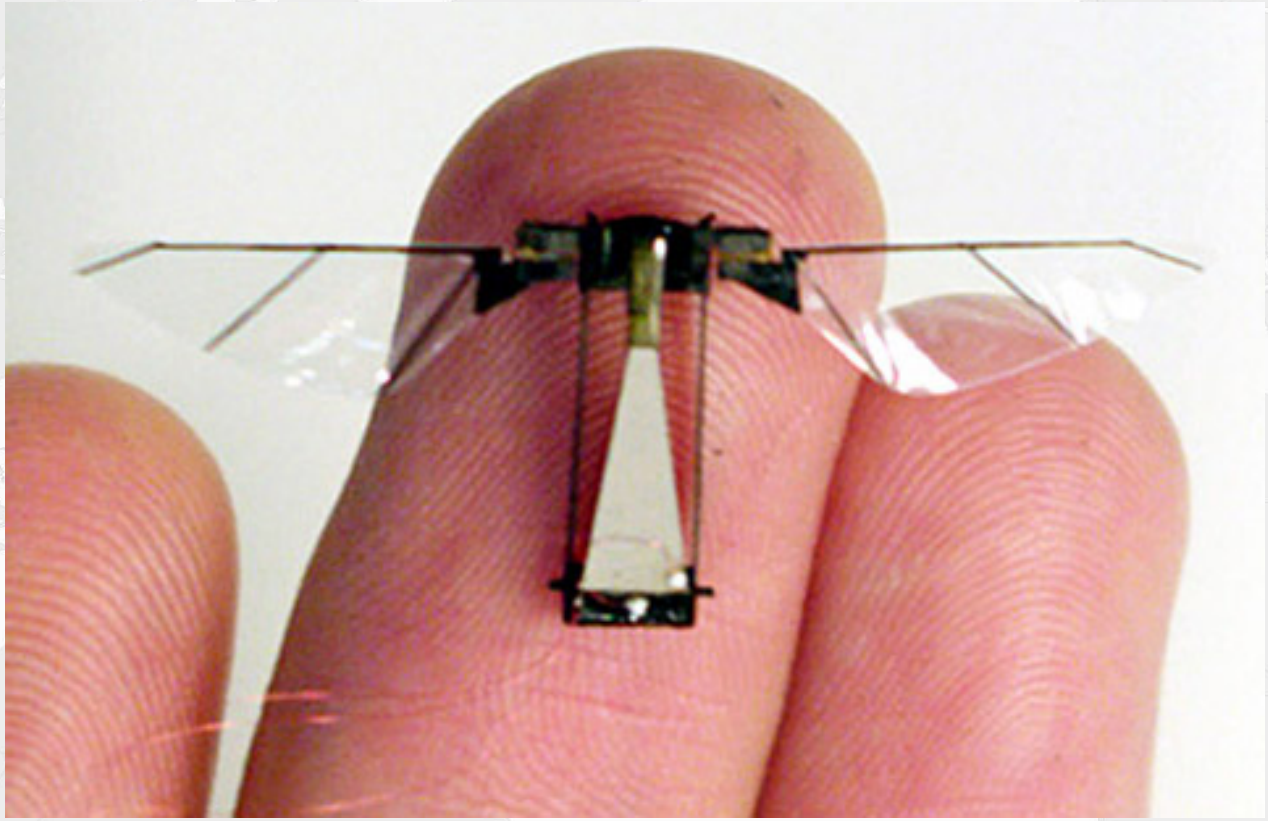


Feedstock for Bulk Materials



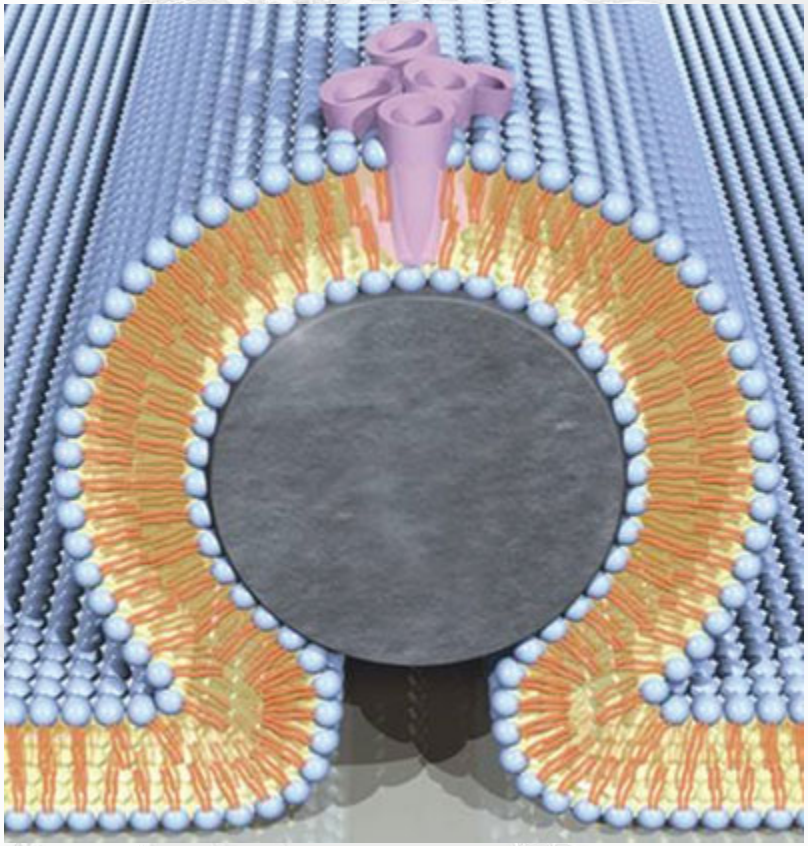
Enzymes for Environmental Remediation

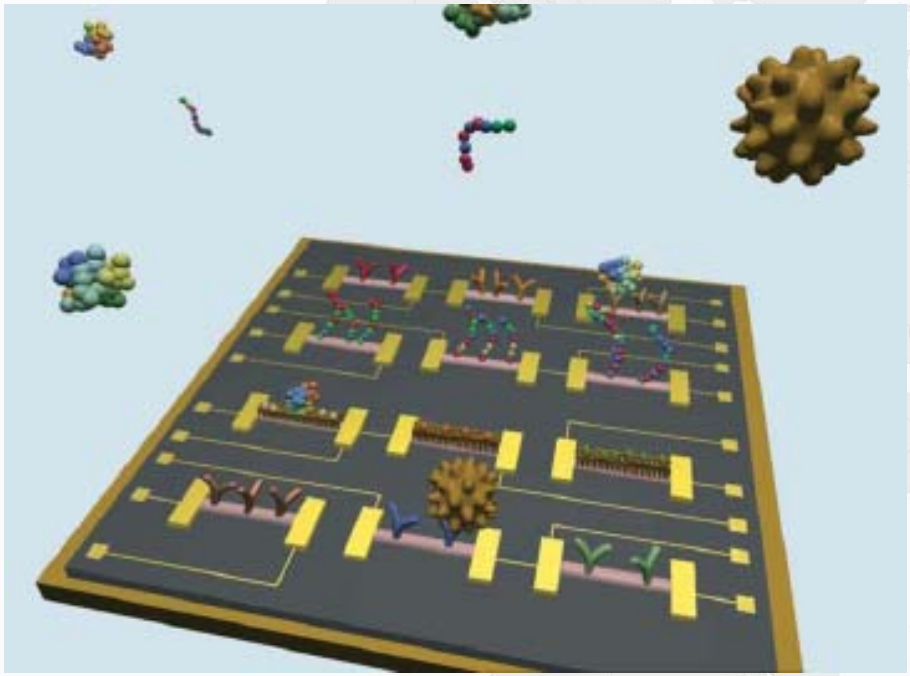
Biomimetic Design of Miniature UAVs



Rough Terrain Mules

Beyond the Limitations of Silicon





Robots Made of Mold